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Application of Heavy Lift Ship Technology to Expeditionary Logistics/Seabasing

by

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14. ABSTRACT
A Center for Innovation in Ship Design study was conducted to investigate the potential use of heavy lift ship technology to facilitate transfer of cargo and personnel in a sea base environment. Emphasis was placed on rough water operations. The Intermediate Transfer System (ITS) utilizes currently available heavy lift ships as trans-shipment nodes to facilitate transfer of vehicles, personnel, and cargo between large inter-theater RO/RO and container delivery ships and smaller intra-theater vessels. Emphasis was placed on higher off-load rates in higher seas. Alternate uses of the concept such as delivery of lighterage to the sea base, reconstitution of forces, and salvage were explored.

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Application of Heavy Lift Ship Technology to Expeditionary Logistics / Seabasing

by Mark Selfridge and Dr Colen Kennell - NSWC Carderock, West Bethesda, MD

SUMMARY

A concept was developed by the Seabasing Innovation Cell within the Center for Innovation in Ship Design (CISD) at the Naval Surface Warfare Center Carderock Division (NSWCCD), West Bethesda, Maryland. The study was undertaken during February-May 2003 with funding provided by the Office of Naval Research (ONR).

The concept, known as the Intermediate Transfer Station (ITS) uses a Heavy Lift Ship (HLS) with a Ro-Ro ship med-moored to its side to enhance efficient at-sea transfer of wheeled and tracked vehicles and extend vehicle transfer into sea states beyond current capabilities. Heavy Lift Ships are traditionally used by the offshore industry to move large floating structures such as drilling rigs and semi-submersibles. Recently, there has been a need to charter such ships to conduct naval ship salvage. The military market continues to grow as these ships are used to deliver limited range vessels such as tugs, mine counter measures craft and barges to an area of operation often over transoceanic distances.

The ITS concept is effectively an alternative use of an existing commercial asset (i.e. a HLS). With only minimal modifications to that asset, it appears that this commercial asset can fill an identified operational gap and expand the operational capabilities of Seabases.

1. INTRODUCTION

The Center for Innovation in Ship Design (CISD) is a partnership, (signed 17-October-2002) between the Office of Naval Research (ONR) and the Naval Sea Systems Command (NAVSEA). Operating under joint-funding, and staffed by the ship design community of NAVSEA, the CISD functions as the Navy hub for supporting the National Naval Responsibility for Naval Engineering, a dedicated effort to ensure the sustained national capabilities to develop innovative designs for Navy ships and submarines. The CISD is an interdisciplinary activity devoted to the creation and development of breakthrough ship design technologies, ship concepts, processes and tools. The Center focuses on People, Knowledge and Innovation to nurture interest and develop experience in the field of naval engineering. The Center hosts Innovation Cells to investigate naval engineering topics of interest.

The CISD Seabasing Innovation Cell at NSWCCD focused on the "*Transfer of Materiel at Sea*." The Intermediate Transfer Station (ITS) concept (see Ref.1) was developed in response to the team's assessment of current operational limitations particularly with respect to the transfer of vehicles at-sea.

This paper summarizes the ITS concept which utilizes Heavy Lift Ship (HLS) technology as a means of conducting efficient at-sea[1] transfer of wheeled and tracked vehicles within the context of Seabasing. A brief

[1] Often referred to as 'in-stream' by the Joint Logistics Over The Shore (JLOTS) community

overview of currently available heavy lift ship capability is included as are details of how the proposed ITS concept is being developed presently (summer 2004) at NSWC Carderock with small scale model testing and planning for proposed full-scale at-sea experimentation. A new-design military specific HLS concept is also described with a focus on at-sea logistics transfer/sustainment as well as vehicle transfer.

2. BACKGROUND

An initial assessment of typical transfer mechanisms and materiel identified ship-based ramps and cranes as the most significant seabased enabling technologies, see Ref.[1]. Both however currently experience significant down-time as the prevailing seastate approaches significant waveheights[2] of approximately one meter (mid seastate 3). In the case of cranes this is due to relative motion, pendulation of the load and limits on the crane bearings. For ramps, relative motion is also key and leads to concerns about ramp cracking due to torsional loading imposed by the relative motion. A potential solution to the crane problem was developed (see Ref.1) but is not discussed here. For the ramp issue, a solution was sought that minimized torsional loading. The ITS was the solution identified and subsequently developed.

3. HEAVY LIFT SHIPS

3.1 HEAVY LIFT SHIP OVERVIEW

The heavy lift ship market is a growing sector. The offshore industry and various massive industrial projects such as refineries or chemical works have encouraged a growing heavy lift sector. The ships have to be naturally robust, and the crew is required to be experts, with a whole range of unusual skills. They are experts in hydraulics, jacking, cutting and welding. The largest vessels of this type are capable of lifting some 73,000 metric tons, with a cargo vertical center of gravity of 30m above the main deck, have a clear deck area of approximately 11,200m^2 (120,800ft^2) and a cruising range of 25,000nm. Their primary customers are the offshore industry where they are often employed to lift, transport and deploy very large and heavy floating offshore structures. They have huge tankage and ballasting capacities to 'sink-under' their cargo and then by de-ballasting 'pick-up' (see Fig.1 or Ref.2) their cargo and transport it to its intended location often many thousand's of miles away.

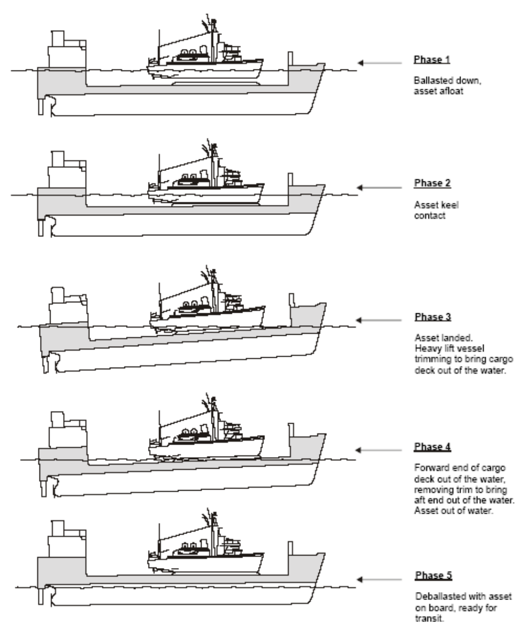

Fig.1 Phases in loading floating deck cargo onto a Heavy Lift Ship

Many of the smaller Heavy Lift Ships can easily increase their lifting capability by fitting removable sponsons along their port and starboard sides. Indeed the recent conversion of the MV Blue Marlin at the Hyundai Mipo Dockyard in South

[2] Average of the top one-third highest waves

Korea resulted in a 50% increase in beam providing an additional ~3,700m^2 of clear deck area and an increase in lift capacity of ~36%. These modifications were made specifically to support the transport of the BP Thunderhorse semi-submersible from its construction yard in the Far East to its intended operating location in the Gulf of Mexico. The BP Thunderhorse is a 60,000 ton lift.

3.2 CURRENT MILITARY USE

Some Heavy Lift Ships are specially designed for their role while others are conversions. An example of the latter is the American Cormorant, a converted tanker operated by the US Military Sealift Command. The American Cormorant is shown here in fig.2 underway and fig.3 at anchor with a typical deck cargo of limited range vessels such as tugs, mine counter measures vessels, barge mounted reverse osmosis water purification plants, harbor cranes etc. that can be transported over transoceanic distances to the theater of operation.

Fig.2 MV[3] American Cormorant underway with a full deck cargo of military assets

Fig.3 MV American Cormorant at anchor with military deck cargo

Both the US and UK military have chartered Heavy Lift Ships such as the Norwegian MV Blue Marlin (fig.4) to return the bomb damaged USS Cole (DDG67) from the Gulf of Aden, Yemen to Ingalls Shipyard in Pascagoula and the Dutch MV Swan (fig.5) to return HMS Nottingham from near Lord Howe Island, Australia to Portsmouth Naval Base following a grounding incident. Both ships had significant openings in their hulls.

While both these cargoes are significant assets in their own right, they represent a fraction of the maximum lifting capacity of these vessels. However, damaged cargo can present other limiting factors such as excessive trim and/or heel that can stretch the operating envelope of even the largest heavy lift ships.

Fig.4 MV Blue Marlin with USS Cole

[3] MV - Merchant Vessel

Fig.5 MV Swan with HMS Nottingham

Two separate lifts were used to transport minesweepers to the Persian Gulf from the US and three lifts were used to bring others back. Prior to ‘piggy-backing’ on a heavy lift ship such vessels made the transoceanic voyage making numerous refueling ‘stops.’ On arrival, up to 45 days were often required for main engine rebuilds and maintenance.

For planned lifts, the Military Sealift Command (MSC) has been used to administer contracts with commercial heavy lift ship operators. For emergency lifts, then NAVSEA 00C (Supervisor of Salvage) is the primary contact.

3.3 COSTS

Neither the US Navy nor the Royal Navy currently own or operate any Heavy Lift Ships. Instead, they have chosen to charter to meet their heavy lift requirements. While the cost of chartering is not insignificant, in cases such as those of the damaged warships USS Cole and HMS Nottingham, a heavy lift was the only option to return the vessels safely to home ports for repair. The cost of an overseas repair (even if permission is granted to do so by the host nation) is likely to cost significantly more and take much longer.

The all-inclusive cost of chartering the MV Blue Marlin for the USS Cole lift was approximately $5.1M USD. Prior to the USS Cole lift, two Minehunters were transported from Ingalls to Kuwait at an all-inclusive cost of $3.5M USD using the same ship. The use of heavy lift ships for military transportation (and salvage) is increasing to the point where it is now considered standard operating practice. MSC report conducting two or three lifts per year presently. The MV American Cormorant is pre-positioned in Diego Garcia and carries port-opening lighterage and small watercraft for the US Army. In 1997, a contract was placed by MSC with Cormorant Shipholding Corporation of Bethesda Maryland for $60.5M USD for a 59-month charter of the MV American Cormorant.

4. HEAVY LIFT SHIP CHARACTERIZATION

It is estimated there are less than fifty heavy lift ships operating worldwide with a few owners dominating the market with their own fleet of ships. The Dutch company Dockwise owns and operates 14 such vessels. However, there are ‘many’ other operators who own and operate only one or two such ships, and appear able to remain competitive in this market place. This may be due to the growing demand for such ships or their availability and base-porting throughout the world.

4.1 CHARACTERIZATION

An internet search of existing heavy lift ships provided sufficient data to characterize important heavy lift ship parameters including deck area, length, draught, beam and deadweight as functions of each other, see figs.6, 7, 8 and 9.

Two fundamental characteristics of HLSs are their weight lifting capacity and the size of their decks to support cargos. The relationship between these two parameters is shown in fig. 6. Deck area data in the plot does not include removeable sponsons. Sponsons used by Tia An Ku and the

jumboised Blue Marlin increase deck area by 24% and 50% respectively.

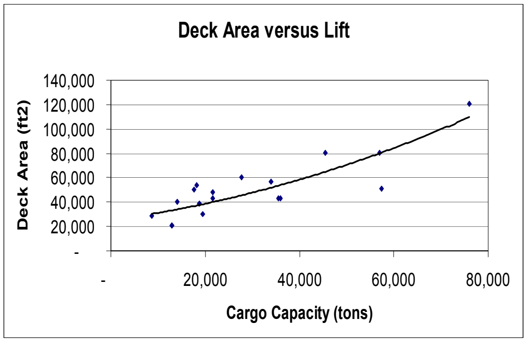

Fig.6 Deck area versus Lift

Fig.6 shows how deck area varies with lift or cargo capacity for a number of currently operating heavy lift ships. The general trend being, the larger the ship the bigger the carrying capability. While the smaller ships can support about a ton per square foot of deck area on average, the average loading decreases to about two-thirds of a ton per square foot for the largest ships.

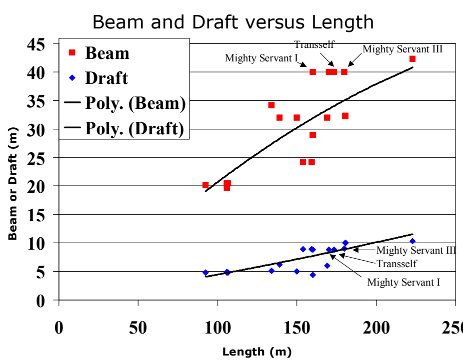

Fig.7 Beam and Draft versus Length

Although there is considerable scatter in the data, Fig. 7 shows that the length to beam ratio of these ships is about 5.

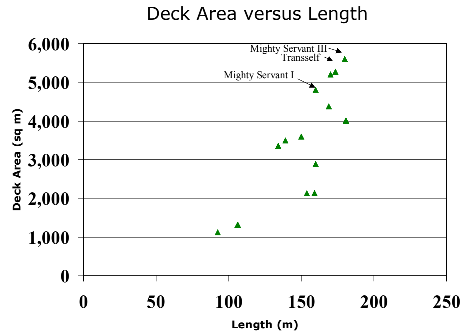

Fig.8 Deck Area versus Length

Fig.8 shows the variation in deck area with length. For the data set used, the length of these heavy lift ships is around 150-180m with clear deck areas ranging from approximately 2-6,000m^2. By comparison, the converted MV Blue Marlin is 224m in length and has a clear deck area of ~11,239m^2 and somewhat dwarfs its nearest competition.

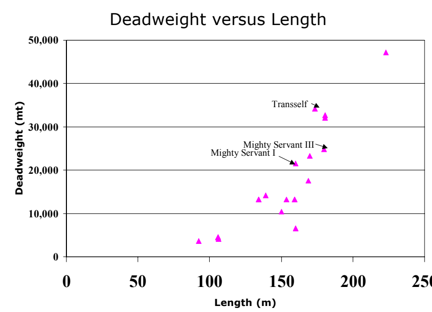

Fig.9 Deadweight versus Length

Typical deadweights (between 10-35,000 metric tons) are shown in fig.9 for some HLS.

5. INTERMEDIATE TRANSFER STATION (ITS)

5.1 CONCEPT DESCRIPTION

The ITS concept utilizes a Heavy Lift Ship in a partially ballasted and heeled condition, (see Fig.10).

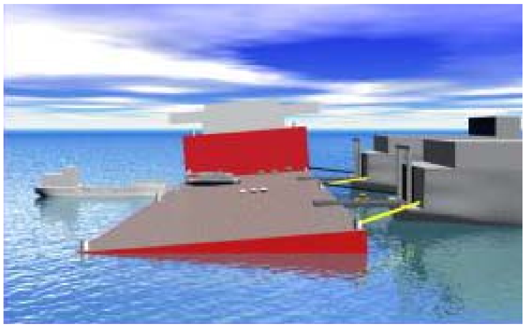

Fig.10 Intermediate Transfer Station

The ship is heeled to ensure one deck edge is just awash while the opposite deck edge is raised. A Roll-on Roll-off (Ro-Ro) ship is then med-moored, that is aligned stern-to, to the raised deck edge of the Heavy Lift Ship. The Ro-Ro ship position is maintained head-to the dominant sea direction. As a result, the HLS is positioned beam to the waves. Consequently, the primary motion response of the Ro-Ro ship is pitch while that of the heavy lift ship is roll. Together they impose a 'wrist-like' motion on the stern ramp of the Ro-Ro ship, thereby minimizing torsional loading and hence ramp cracking.

The large draft heavy lift ship is beam-on to the dominant sea direction; this provides a relatively sheltered environment on the lee-side. Coupled with the lee-side deck edge being awash, this enables lighters such as the Landing Craft Utility (LCU) to interface with the heavy lift ship in a relatively benign environment. Landing Craft Air Cushion (LCAC) craft have to be loaded/unloaded 'off-cushion'. The deck edge awash facilitates the LCAC 'boarding' the deck of the Heavy Lift Ship to conduct its transfer operations. Since LCACs can negotiate a one-meter high obstacle, small angles of ship roll motion due to passing waves do not present a major problem.

The raised deck edge or 'windward' side of the heavy lift ship reduces the drop down angle of the Ro-Ro stern ramp, and more significantly provides a 'sea-wall' to resist incident wave action, reducing the potential for water on deck.

5.2 HEEL ANGLE & SEASTATE

The heel angles required are modest and will generally be less than four degrees. The heel angle will be set by consideration of the expected maximum sea-state (for the duration of the transfer) in the area of operation. This is because sea-states imply wave-heights and to minimize the amount of water on the deck of the heavy lift ship, the freeboard on the 'high-side' should be set to 'block' the particular wave-heights expected. Once the preferred freeboard has been determined, and the beam of the ship is known, the angle of the deck can be calculated. Larger beams result in smaller angles, for the same sea-state / wave-height requirement. Flooding (or ballasting) tanks on one side of the ship will cause the ship to heel over to that side.

It is worth noting that removeable deck edge sponsons are used on HLS's to increase beam and deck area. Use of such sponsons is an alternative means to reduce heel angle.

Stability and safety of the HLS while ballasted in this manner is a concern. However, calculations (see Ref.1) for a small-medium sized heavy lift ship, ~30,000 ton displacement, showed only a 4% reduction in intact stability from the upright condition for a 5 degree angle of heel. This reduction is negligible. A 70 ton M1A1 tank driving across the full breadth of the deck of a heavy lift ship causes less than 1 degree of heel. This change will be less for a larger ship and does not account for any mooring forces and weight of stern ramps that should reduce the tendency to 'roll/heel.'

5.3 POSITIONING/MOORING

Critical to the ITS concept is the ability to med-moor large Ro-Ro ships to the side of a HLS. While commercial and military ships routinely med-moor to quays, med-mooring to floating structures in the open seas is not routine. It is worth noting that similar size ships are brought together alongside to conduct transfer operations at sea. Development of mooring techniques that are safe and reliable are crucial. These techniques are expected to require enhancements to the HLS and Ro-Ro's such as warping winches, bitts, chocks, and high-strength mooring lines. Tugs may be required as well. Appropriate ship handling procedures will be required as well for both the HLS and Ro-Ro's. In addition, a straight forward break-away process will be needed to allow safe separation of the ships when confronted with deteriorating weather or emergencies.

The views of ship and small craft operators who will be interfacing with the heavy lift ship need to be sought and discussed with the benefit of the heavy lift ship operator experience. Heavy Lift Ships may appear simple, but they are sophisticated ships and there will be some familiarization required by all vessels and personnel who intend to interface with them.

The ability to keep the med-moored Ro-Ro ship 'pointed' into the prevailing seas is crucial to accomplish the 'wrist-like' motion between the two ships as well as create a lee for the smaller craft. A simple solution to this problem is to use tugs to control position of the ITS. A more elegant approach is to use thrusters and propellers on both the HLS and Ro-Ro ship to maintain the preferred positions. Most HLS's and Ro-Ro's used by the military are equipped with thrusters.

6. CONCEPT DEVELOPMENT

Initial briefings of the Intermediate Transfer Station concept generated interest in full-scale in-stream (i.e. at-sea) experimentation with the concept from within the US Navy and confirmed offshore industry interest also. As such, the CISD has liaised with the Naval Warfare Development Command (NWDC) who has responsibility for coordinating the Sea Trials program. The formal process has been initiated for a Sea Trial.

6.1 SUB-SCALE TESTING

To assist in the planning for the full-scale demonstration and to reduce risk in the ITS concept, initial sub-scale testing at NSWCCD was undertaken during Summer 2004. The testing was completed by another NSWCCD/CISD Innovation Cell supported by four summer interns. Funding was provided by NAVSEA who jointly sponsor the CISD with the Office of Naval Research (ONR) as part of their National Naval Responsibility for Naval Engineering program.

The objectives of the sub-scale testing were to characterize the seaway on the lee-side of the ITS relative to the windward-side, determine the performance of the configuration in a seaway with particular attention to water on deck, establish mooring line forces, quantify the response of the heavy lift ship and determine the relative motions of the three vessels in the configuration. The effect of changes in heading and wave-height (i.e. seastate) were investigated. Each sea-state covers a range of wave-heights. Modal period was also an important parameter particularly since many sea areas have characteristic modal periods which are close to the natural frequencies of lighterage and small watercraft potentially resulting in seaway induced roll/pitch/heave resonance. The tests were videoed.

It was anticipated that the planned testing may identify additional combinations and configurations that could help to define the ITS performance more confidently, and so a limited amount of time was allocated for this.

All three sub-scale models had to be manufactured specifically for the testing and the availability of hullform geometry/definition dictated which heavy lift ship could be used. This was the Chinese registered Tia An Ku operated by NMA. Ideally, a larger HLS with a larger beam would have been chosen as the resulting heel angle or deck inclination is a direct function of the sea-state and the beam of the ship in question - the smaller the beam, the larger the heel angle for a given freeboard/seastate. However, it is reasonable to suggest that if the performance of a 'small' heavy lift ship is acceptable, then the performance of a larger ship will be better. It would be desirable to use a larger heavy lift ship for the full-scale at-sea demonstration.

The three models have a scale factor of 158:1 and the testing was conducted in the 140 foot tank at NSWCCD from seastate 2-7.

Analysis of the data, showed a reduction in wave-height between 30-60% dependant on the incident wave-height and modal period. No deck wash was observed until seastate 6 and even then only minimal. Testing concluded unlimited operations in seastate 3, and possible operations in seastate 4. While it is not expected that transfer operations could take place in seastate 7, testing to this extreme revealed that it would unnecessary to 'break' the med-mooring between the HLS and the Ro/Ro ship – this is significant as breaking away and re-mating is expected to be time-consuming and complex.

6.2 Full-scale Sea Trial - progress

To date, the formal Sea Trial process has been initiated. Paperwork has been submitted to the Sea Trials Coordination team for consideration at the next quarterly meeting. NAVSEA 05D1 have provided funding to develop a more thorough full-scale trials plan leveraging the knowledge and performance data gained during the sub-scale testing, but also through discussion with heavy lift ship operators and the expected user community in the US military.

The intention will be to demonstrate the concept at sea. This will involve engaging operators of Heavy Lift Ships, Landing Craft, Ro-Ro ships, High Speed Ships and possibly seaplanes with a view to establishing interest, concerns, availability, costs, individual requirements etc. to assist in the preparation of a formal proposal. In addition, it will be beneficial if wheeled and/or tracked vehicles are available to perform the transfer at-sea from say a Ro-Ro ship onto the heavy lift ship deck then into a landing craft. Transfer in reverse will be equally important.

A significant element will be the development of suitable interfacing techniques for the ships/watercraft and adequate emergency and contingency arrangements. Some of this could and should happen prior to any planned at-sea demonstration.

It is anticipated that funding may come from various sources rather than a single source. NSWC Carderock Code 28 would assume the role of planner and coordinator with expert knowledge of the expected performance and potential risks.

7. APPLICATION OF HEAVY LIFT SHIP TECHNOLOGY AS A SEABASING ENABLER

Seabasing implies different meanings to different authorities; regardless of the Seabase configuration, a current and future problem will be the transfer of materiel at sea. The current goal is to continue operations through sea-state four, see ref.3, where the maximum significant wave height is 2.5m.

The primary purpose of the ITS concept proposed here is to provide efficient at-sea transfer of wheeled and tracked vehicles in higher sea-states than is currently achievable with barge and causeway sections. However, a heavy lift ship is inherently a multi-purpose seabasing asset / facility with potential to fulfill a number of seabasing needs. Initially, it can provide efficient transoceanic transport for delivery into theater of lighters, small ships, and other essential Seabasing infra-structure components. Then, in ITS mode, it can provide the at-sea interface for small and large vessels through which they can exchange materiel, primarily vehicles. To maintain the tempo of the operation and ensure sustainment of forces ashore, the large clear deck area (see fig.11) can serve a multitude of functions, including stowage and repackaging of containerized and/or palletized cargo, open-air fueling/de-fueling, arming/de-arming, and reconstitution of the force.

Current washdown/de-contamination of military hardware happens ashore within the relatively safe confines of the 'iron-mountain' which will no longer exist if Seabasing is to become reality. Hence, in future there will be a need to conduct wash-down afloat. The large clear open deck (with good overboard drainage) provides an almost ideal environment for wash-down. A portable wash-down facility might be readily deployable in containerized form and assembled on the deck of the ITS.

Fig.11 Available deck area

Reconstitution and selectivity of materiel come hand-in-hand. Both place significant demands for working space if efficiency is important. Space on board existing, and most likely future, military ships, is very limited, certainly in the initial stages of an operation where the emphasis is on getting materiel to the intended area of operation quickly. The heavy lift ship large deck area can enable selectivity from a densely packed Ro-Ro ship.

The large deck of the HLS can also provide a 'safe-haven' for small craft in heavy weather or during periods of extended non-use. If the Seabase is to remain for extended periods the deck area can also support scheduled maintenance, emergency dockings, inspection and repairs, or direct support to air operations (helicopters and/or seaplanes).

A typical military deck cargo (see fig.12) weighs significantly less than the capability of even the smaller heavy lift ships. This implies significant spare or unused tankage in these ships that could usefully be filled with fuel to support seabased operations; perhaps as a refueling station for lighters and vehicles to avoid them having to transit elsewhere to refuel.

Fig.12 Heavy Lift Ship offloading

One final point on the heavy lift ship deck is that it is self deployable and can be easily reconfigured – it can easily move as the objective moves.

8. FUTURE CONCEPT

The ITS concept proposed here was based initially on currently available heavy lift ships. Should the US/UK military decide to acquire its own capability in this area, there is scope for conversion, direct purchase or new-build.

Existing heavy lift ships have evolved to support their customers, which today are primarily the offshore industry. The offshore industry demand heavy lift ships with increasing payload or deadweight capability, often in the tens of thousands of tons range. Military lift needs are biased towards the lighter end (<10,000 tons) but with a desire for lots of clear deck area. In terms of speed, most heavy lift ships operate at approximately 12-15 knots with and without deck cargo and some are single screw vessels. This is somewhat lower than 'normal' commercial *and* military practice.

A military specific heavy lift ship may be designed for higher speeds (say 20-25kts), lighter payloads (<10,000 tons) and lots of deck area (say ~10-15,000m^2). A large beam is a desirable factor as discussed in section 5.2. Other desirable military features might include an organic container capable crane and on-deck container mover(s), numerous deck fittings to secure deck cargo, chocks and bits for mooring, fendering, tankage for lighterage and vehicle fuel, reverse osmosis plants to provide water for wash-down etc. In addition, advanced dynamic positioning systems and mooring systems may be required to fully exploit the seabased potential of the ITS.

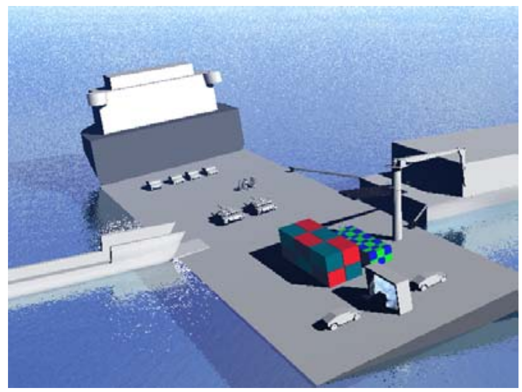

Fig.13 Military ITS - Artists impression

Fig.13 shows an artists impression of some of the upper deck additions and uses that a military specific heavy lift ship might have. While addition of such features will affect the weight and stability of the HLS, the impacts will be well within the capabilities of Heavy Lift Ships.

9. CONCLUSIONS

Reliable transfer of wheeled and tracked vehicles at-sea is currently limited to seastate 2, see ref.[4] pages 2C1-26 and 2C1-37.

Reconstitution of materiel (particularly vehicles) at sea has significant ship impacts particularly in terms of deck area.

Military use of Heavy Lift Ships is increasing for transoceanic transport

(typically two or three lifts per year) and marine salvage. The US Navy does not currently own any Heavy Lift Ships. Instead, Heavy Lift Ships are chartered on an as required basis.

The Intermediate Transfer Station concept enables very efficient at-sea transfer of wheeled and tracked vehicles, and initial sub-scale testing of the ITS concept shows unlimited operations in seastate 3 and possible operations in seastate 4. Moreover, using the heavy lift ship as a transporter could have significant impacts on the design and total cost of planned and existing military ships that carry their own lighterage together with the supporting infrastructure. Increased military use and awareness of the potential (and readily available) military capability such vessels offer may strengthen the need for the US Navy to own and operate their own Heavy Lift Ship(s). The MV American Cormorant was a tanker that was converted. Second hand tankers are relatively cheap and plentiful. The conversion costs are also affordable.

The technology exists today and this concept appears to meet an identified operational gap at minimal cost. It is evident (even without operational analysis) that the ITS, is an effective Seabasing logistics enabler. The use of the MV American Cormorant by the US Army is reported (ref.3) to enable force projection in about a third the time when compared with their *previous* practice. The inherent adaptability and robust nature of these ships maximizes their ability to be readily changed to effectively support the progressive stages of an operational engagement from the sea.

Currently, the outstanding risks lie in the areas of mooring, connecting and breaking away, position/station keeping, and performance in a seaway. Current sub-scale testing is addressing the latter and the proposed full-scale trial will explore all of these areas more fully, while demonstrating this affordable capability.

10. RECOMMENDATIONS

It is recommended that a full-scale Sea Trial or at-sea experiment be conducted. This will require a significant planning and coordination effort to integrate the roles of the ships and commands involved. Supporting operational effectiveness analysis is likely to provide further confirmation of the expected 'pay-off' in terms of military effectiveness and so should be commissioned.

The Sea Trial or at-sea experiment will have greater impact if current 'in-vogue' assets such as the commercial high speed catamarans (e.g. HSV-X1, TSV-1X, HSV-2, X-Craft) are involved.

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NOMENCLATURE

CISD – Center for Innovation In Ship Design
HLS – Heavy Lift Ship
HMS – Her Majesty's Ship
HSV – High Speed Vessel
ITS – Intermediate Transfer Station
LCAC – Landing Craft Air Cushion
LCU – Landing Craft Utility
LMSR – Large Medium Speed Ro-Ro
MV – Merchant Vessel
NAVSEA – Naval Sea Systems Command
NSWCCD – Naval Surface Warfare Center Carderock Division

NWDC – Naval Warfare Development Command
ONR – Office of Naval Research
TSV – Theatre Support Vessel
USS – United States Ship

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